Quantum Networking and Sensing using a Diamond Nanophotonic Circuit

Completed Technology Project (2016 - 2020)

Project Introduction

Quantum mechanics offers new ways to compute, communicate, and measure that are inherently more powerful than classical physics would allow. Of particular interest is the notion of a quantum network, where stationary and flying quantum bits (qubits) are transferred between remote nodes. Two strange quantum mechanical phenomena superposition and entanglement allow such a quantum network to be used for feats impossible in a classical network. For example, a network of satellites with entangled qubit nodes would allow for perfectly secure communications, as well as more powerful distributed computing. Connecting a rover to the network would allow it to perform an ultraprecise quantum mechanical measurement by entangling one or more probe qubits to a sample, and then teleporting these qubits through the network for processing. The first links of such quantum networks have been demonstrated using Nitrogen-Vacancy (NV) centers in diamond. These NV centers are atomic defects in the diamond crystal that are both highly stable on a quantum mechanical level and easy to interact with optically, making them ideal for use in a network of qubits. The advantage of using this system over other candidates like cold atoms or trapped ions is that it can be operated over a wide range of temperatures and in a variety of atmospheric conditions, giving it great potential for use in space-based devices. However, current quantum networking schemes using NVs are limited by photon losses, restricting the efficiency - and thus scalability - of these systems. My research seeks to overcome this obstacle and develop a many-NV quantum node integrated onto a photonic circuit chip. To do so, I will integrate NV centers with optical nanocavities; through an effect called Purcell enhancement, these structures should increase the rate at which individual NVs emit photons that are coherent, that is, photons that maintain their quantum properties. Increasing the number of coherent photons emitted by an NV will increase the rate at which it can be entangled with other NVs and thus used for quantum networking. I will also need to improve the efficiency with this increased emission can be collected from the NVs. Doing so will require incorporating novel structures like optical waveguides and tapers in with the diamond cavity. These techniques will allow me to efficiently route and collect the photons emitted from single NVs and use them for entanglement with other NV centers. Once I have accomplished this, the last stage will be to place everything on a single chip. Integrating photonic circuits onto this chip will connect these many qubits and form a sort of quantum processor that can serve as a sensing device or a node in a quantum network. The properties of quantum mechanics would allow this node to communicate securely with other network points, or to perform distributed computations along with other devices in the same network. Quantum technologies for precision measurements already form the basis for the world's most accurate clocks and sensors, and a tailoring of this quantum node into a self-contained processor would allow for the creation of a light-weight quantum metrology device. For example, incorporating these chips into satellites would enable precision time-keeping in turn improving position, navigation, and timing for terrestrial and

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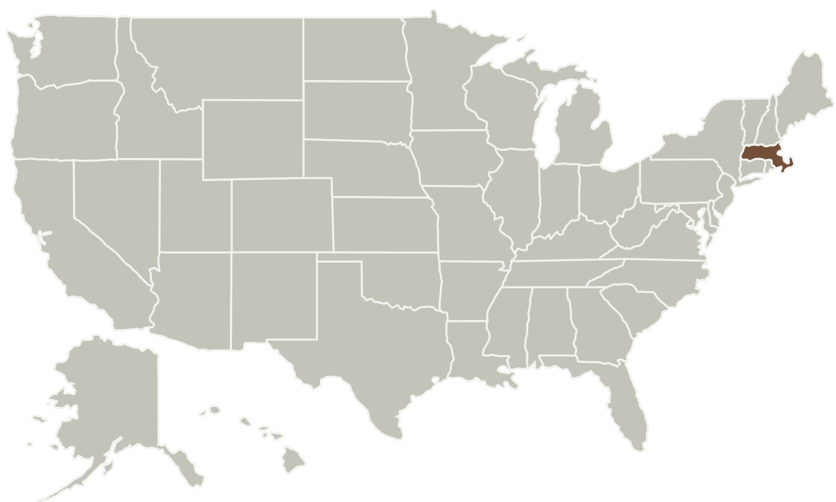
space applications. These new abilities will extend mankind's ability to learn and explore, both at the level of fundamental physics and on the scale of probing planets, moons, comets, and ultimately deeper space.

Anticipated Benefits

Tailoring of this quantum node into a self-contained processor would allow for the creation of a light-weight quantum metrology device. For example, incorporating these chips into satellites would enable precision time-keeping in turn improving position, navigation, and timing for terrestrial and space applications. These new abilities will extend mankind's ability to learn and explore, both at the level of fundamental physics and on the scale of probing planets, moons, comets, and ultimately deeper space.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts

Primary U.S. Work Locations
Massachusetts

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Massachusetts Institute of Technology (MIT)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

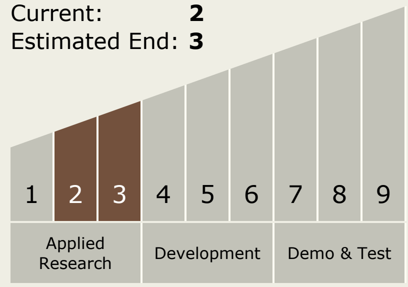
Dirk Englund

Co-Investigator:

Eric Alexander Bersin

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  - └─ TX05.5 Revolutionary Communications Technologies
    - └─ TX05.5.2 Quantum Communications

Target Destinations

Earth, Others Inside the Solar System